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The Monsoon Experiment MONEX

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Dr. P. K. Das
Director-General of Meteorology
India Meteorological Department
New Delhi

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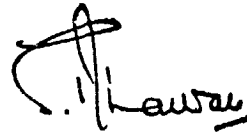
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Preface

India lives on the Monsoon. This complex phenomenon affecting the lives of millions is yet to be fully understood. A year long Monsoon Experiment organised by the international scientific community as a part of the Global Atmospheric Research Programme has just ended. Indian scientists actively participated with many others in gathering data from meteorological satellites, sounding rockets, aircraft, land and ship-borne stations. The Indian effort was organised and led by the India Meteorological Department (IMD). This note by Dr. P. K. Das, DG, IMD describes MONEX and gives a glimpse of the results which are expected to become available when all the data gets analysed and studied.

A handwritten signature in black ink, appearing to read 'S. Dhawan', with a stylized flourish above the name.

S. Dhawan
Chairman, ISRO

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The Monsoon Experiment — MONEX

A Global Atmospheric Research Programme (GARP) was organised by the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) in 1967. Under this programme a Global Weather Experiment is being conducted for one full year beginning on December 1, 1978. This is one of the biggest ever international experiments — on a global scale — for observing the earth's atmosphere.

Some idea of the dimensions of this experiment may be had from the fact that during May of 1979 as many as 52 research ships were deployed over the tropical oceans between the latitudes 10°N and 10°S, while 104 aircraft missions were successfully completed over different parts of the Pacific, the Atlantic and the Indian Oceans during the same period.

Monsoon features

Of considerable interest to India is a sub-programme of the Global Weather Experiment. This is the Monsoon Experiment—popularly known as MONEX. Its purpose is to study the contribution of the monsoons, in different parts of the world, to the earth's atmosphere.

There are two main monsoon systems. The winter and northern monsoon is the consequence of north-easterly winds blowing over the oceans, and the westward passage of disturbances to the south of the equator. The winter rains over the southern half of the Indian peninsula are associated with the winter monsoon. But, by far the more extensive system is the summer monsoon, when south-westerly winds flow over the Indian Ocean and seasonal rains extend over India and many countries in South-East Asia. The duration of the summer monsoon is roughly a hundred-day period, beginning with the end of May each year.

The monsoon is also observed over Africa, especially its western and central parts. There appears to be only one monsoon over Africa, and this is associated with the northern summer.

MONEX management centres

In view of its seasonal character, the Monsoon Experiment (MONEX) was divided into the following three parts :

- (i) Winter MONEX from December 1, 1978 to March 5, 1979 ; which covered the eastern Indian Ocean and the western Pacific Ocean along with the land areas of Malaysia and Indonesia.
- (ii) Summer MONEX from May 1, 1979 to August 31, 1979. This covered the eastern coast of Africa, the Arabian Sea, the Bay of Bengal and the adjacent land areas. It also extended over the Indian Ocean from 10°N to 10°S.
- (iii) West African Monsoon, or WAMEX, over the western and central parts of Africa for the duration of the northern summer.

International MONEX Management Centres were set up in Kuala Lumpur and in New Delhi to supervise the winter and summer components, respectively, of the Monsoon Experiment. A large number of scientists from different countries visited and worked at these Centres to plan the experiment. A similar centre was set up in West Africa for WAMEX. To maximize the data output, plans have

been drawn up for the transmission, storage and retrieval of data. The data have been divided into the following three categories :

- (a) Level I — raw primary data, such as the original record of different sensors ;
- (b) Level II — meteorological variables, such as wind speed and direction from raw data ;
- (c) Level III — processed data in the form of charts and weather maps.

Some of the data will be processed on real time, while others will be processed later. The Level III data are expected to become available two years after the termination of the experiment, but a good part of the Level II data will become available six months after the field phase of the experiment. Indian scientists at the International MONEX Management Centre in New Delhi have drawn up computer programmes for real time checks on the consistency and accuracy of incoming data.

Surface based platforms

Among the surface based platforms, the major contributions for Summer MONEX were the following :

- (a) five research ships from the USSR
- (b) three civilian research aircraft from the USA
- (c) four research ships and one aircraft from India
- (d) one research ship from France

The five research ships from the USSR moved into the Bay of Bengal after completing the Arabian Sea phase of the experiment. They cruised in the form of a moving polygon, with a spacing of approximately 400 km between adjacent ships. This is illustrated in Figure 1.

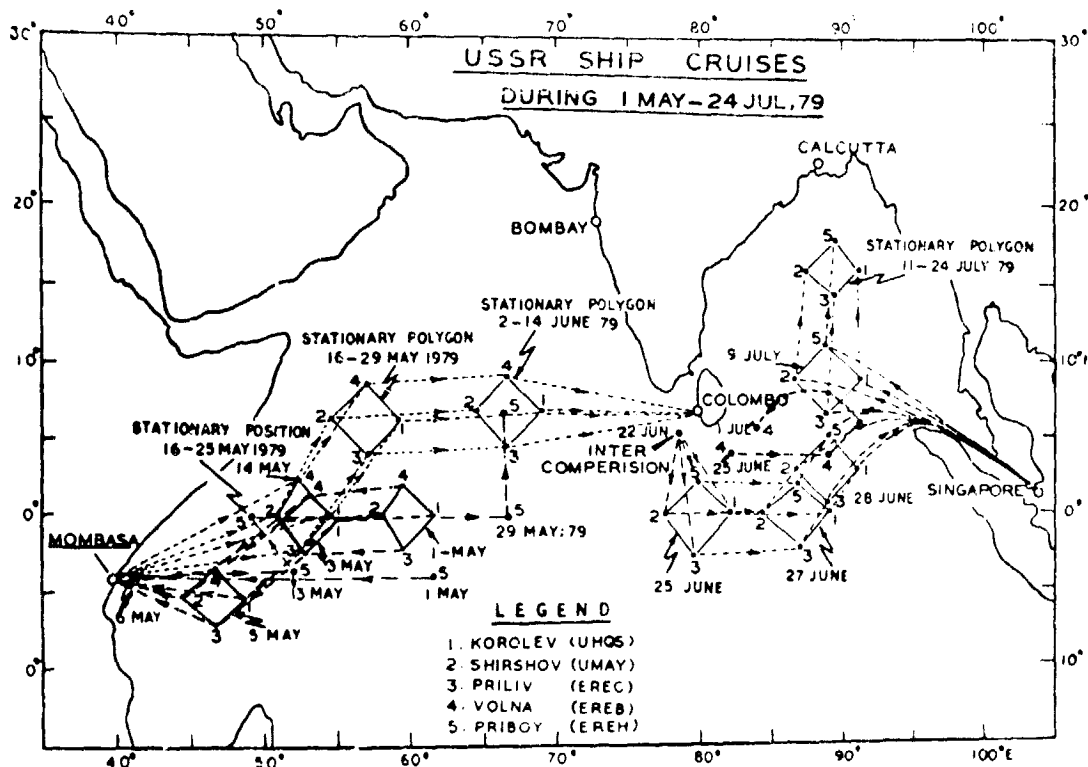


Figure 1. USSR ship cruises

Valuable data were obtained by the flight missions of three civilian research aircraft from the USA. Of particular interest were data on the radiation balance of the earth-atmosphere system. They measured both the incoming radiation from the sun and the radiation emitted by the earth's surface. The latter was, in turn, modified by overlying clouds and aerosols in the atmosphere. The reflectivity of the soil was another important variable, which was measured from the air. The US aircraft were equipped with dropwindsondes (Figure 2). These instruments were fitted with meteorological sensors and a tiny parachute. The sensors transmitted their data directly to the aircraft as they descended with the parachute. Forty-six scientific missions were flown by US aircraft for the Arabian Sea phase of



Figure 2 : Dropwindsonde being launched from US aircraft

MONEX, with a similar number for the Bay of Bengal part of the experiment. The instrumented interior of a typical aircraft for data collection is shown in Figure 3.

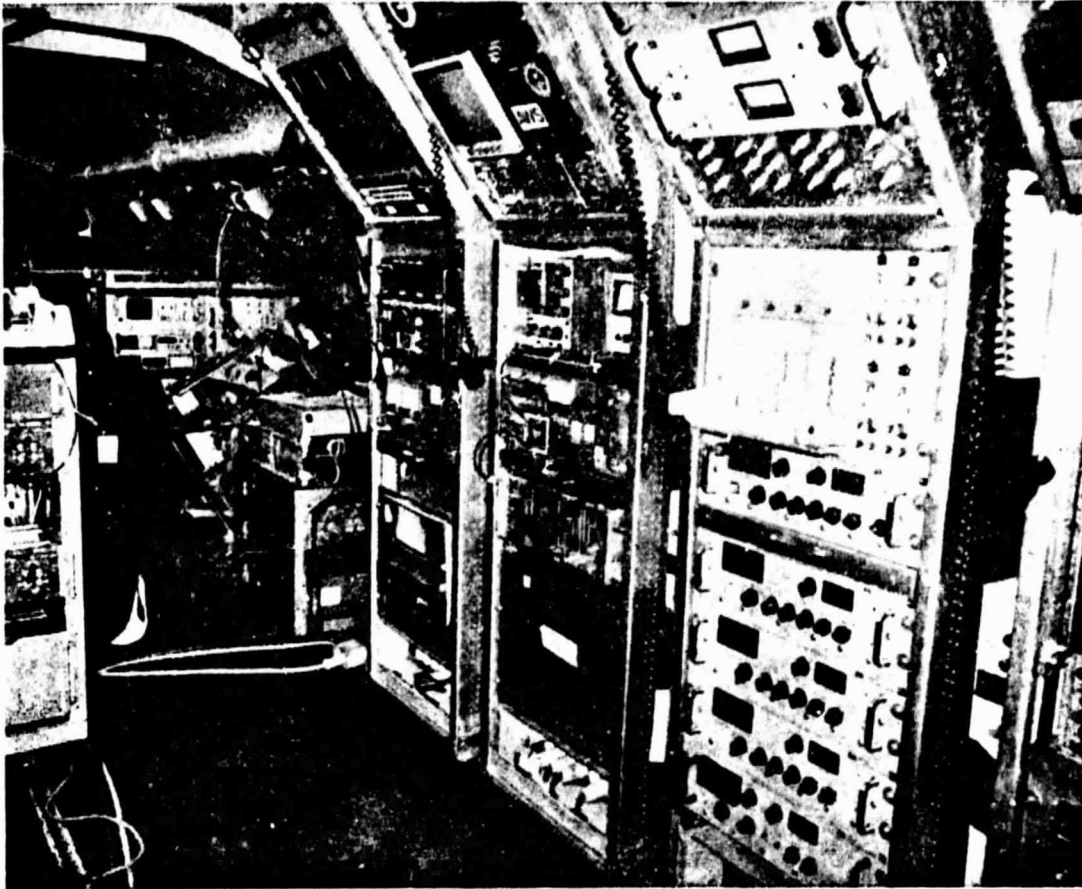


Figure 3 : The instrumented interior of a typical aircraft for data collection.

The Indian ships were equipped, for the first time, to measure upper winds. This was achieved with the help of balloon-borne Omegasondes. It used a system based on the intersection of radio beams, on very low frequencies, to monitor the track of a balloon which, in turn, provided a measure of the speed and direction of the wind. One of the ships ran into very disturbed sea. It was stationed fairly near to a cyclone which later struck the coast of Andhra Pradesh. Observations were recorded with much difficulty.

Flights by an Indian aircraft, belonging to the National Remote Sensing Agency, for monsoon studies represent a creditable achievement which augurs well for the future. This aircraft recorded the following parameters in analog form :

- (i) Total air temperature
- (ii) Static and dynamic pressure
- (iii) Dew point
- (iv) Liquid water content
- (v) Radiometric surface temperature
- (vi) Radio altitude

Some of the data were obtained under conditions of turbulent and disturbed weather, associated with depressions and tropical cyclones. These observations owe a good deal to the skill and courage of the aircraft crew. Typical flight tracks of all the aircraft (US and Indian) taking part in MONEX over the Arabian Sea are shown in Figure 4.

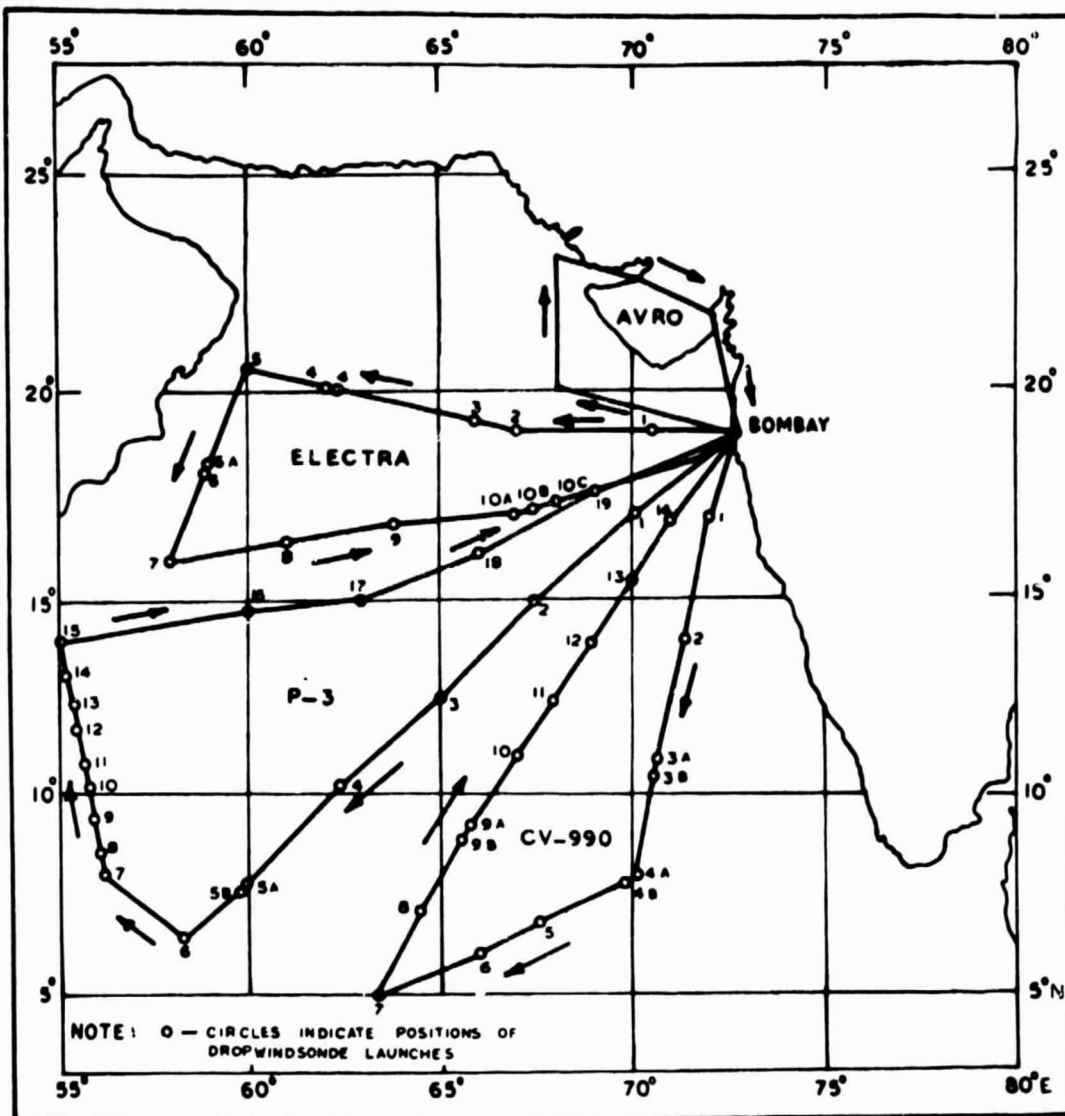


Figure 4: Flight tracks of US and Indian aircraft missions on 27 June 1979

France contributed a ship to track the path followed by the monsoon air with the help of balloons that flew at a constant altitude. These balloons were designed to reveal the trajectory of the air as it approached the Indian coastline during the southwest monsoon.

The observation programme of the India Meteorological Department was considerably increased and intensified to meet the MONEX requirements. A number of additional stations were set up to measure upper winds, along with a network of 8 stations for measuring solar and terrestrial radiation profiles with balloon-borne equipment.

A boundary layer programme for measuring meteorological elements near the earth's surface was designed, jointly, by the Indian Institute of Science, Bangalore and the US MONEX Project. This

programme achieved a series of extremely interesting observations of the flux of momentum, sensible heat and water vapour at Digba, a coastal station near Contai in West Bengal. These observations were made with a 10 m mast and they represent, probably for the first time, measurements of the flux of atmospheric variables close to the earth's surface under Indian conditions. A very sensitive Lyman-alpha hygrometer was used to measure water vapour fluxes.

There were two other programmes which considerably enhanced the overall importance of MONEX. The first was designed to investigate the lower stratosphere with the help of rockets launched from (i) Thumba, (ii) Sriharikota, and (iii) Balasore, with a frequency of approximately one per week. This was organised by the Indian Space Research Organisation (ISRO). The importance of this programme arises from the fact that it will enable us to assess, probably for the first time, the response of the stratosphere to the lower tropospheric monsoon circulation in a coordinated manner. One of the rocket stations was located near the equator; consequently, this programme could be valuable for studies on the propagation of the equatorial waves in the lower stratosphere. It is expected to continue this programme with further expansion in the near future.

The second programme was concerned with oceanography. Vertical profiles of ocean currents and other oceanographic elements were measured by all ships taking part in this experiment. These data, apart from being of interest to oceanographers, will also interest meteorologists, because they will provide the input for ocean-atmosphere coupled models.

Space platforms

One of the attractive features of MONEX was the response it generated from many countries. Several countries agreed to intensify their national observational programmes during the operational phase of MONEX and to communicate their data to the International MONEX Management Centre in Delhi.

Weather satellites are now capable of measuring an impressive array of meteorological elements. Television cameras fitted on these satellites observe the structure of clouds beneath them and transmit them, automatically, to a ground station located on the earth. This is referred to as an Automatic Picture Transmission (APT) system, and the receiving point on the earth is an APT station. A network of eight APT stations was set up in India during MONEX.

Weather satellites are of two broad types : (a) those which orbit round the earth from Pole to Pole, and (b) those which rotate round the earth with the same speed as that of the earth round its own axis. The latter are geostationary satellites, because they appear to be stationary with respect to the earth. The geostationary satellites have the advantage of being able to monitor, continuously, any part of the earth's surface round the clock.

A beginning towards reception of data from the geostationary satellites was made during MONEX. A geostationary satellite—GOES INDIAN OCEAN—was specially moved to a location on the equator at 60° E to cover the MONEX region. Clouds and cloud clusters observed by GOES were beamed towards Bombay by another geostationary satellite, METEOSAT, which was launched earlier by the European Space Agency. Cloud imagery from GOES were first received at Lannion in southern France, and thence transmitted to METEOSAT for onward communication to Bombay. Ground reception facilities were set up at Bombay for this purpose. One of the pictures received at Bombay during the early phase of the monsoon is shown in Figure 5. The clarity of the Indian land mass is remarkable. Facilities were also provided at Dacca in Bangladesh for receiving cloud images from another geostationary satellite launched by Japan. Collaboration between India and Bangladesh thus provided us with satellite coverage for both the western and the eastern sectors of the MONEX region.

Scientific objectives

MONEX was an exercise at one-time data collection. The greatest value of this experiment lies in the expectation that it would reveal those features of the monsoon, which we need to monitor every year for anticipating its performance. The prolonged drought in the current monsoon has once again emphasized the importance of long range prediction of monsoon rainfall. There are three facets on which we require immediate improvement in our prediction capability. They are :

- (i) an indication of the likely dates of onset and withdrawal of the monsoon over different parts of the country,
- (ii) a forecast of the total quantum of monsoon rainfall during the hundred-day period from beginning of June to mid-September,
- (iii) likely periods of either heavy or lean rainfall leading to floods or droughts during the monsoon season.

There are several important crops in our country, which are grown in areas that depend critically on rainfall. Paddy is an example, because the main rice producing regions are rainfall dependent ; consequently, an indication of the monsoon features, which we have enumerated above, are important for the periods just prior to sowing, transplantation, and, finally, the harvest.

There are fairly well identified lines on which research could immediately commence after the MONEX data become available. One of them is concerned with the earth-atmosphere radiation balance. There is a delicate balance between the total energy which we receive by way of solar radiation, and the radiation that is lost to space from the gaseous envelope that surrounds the earth.

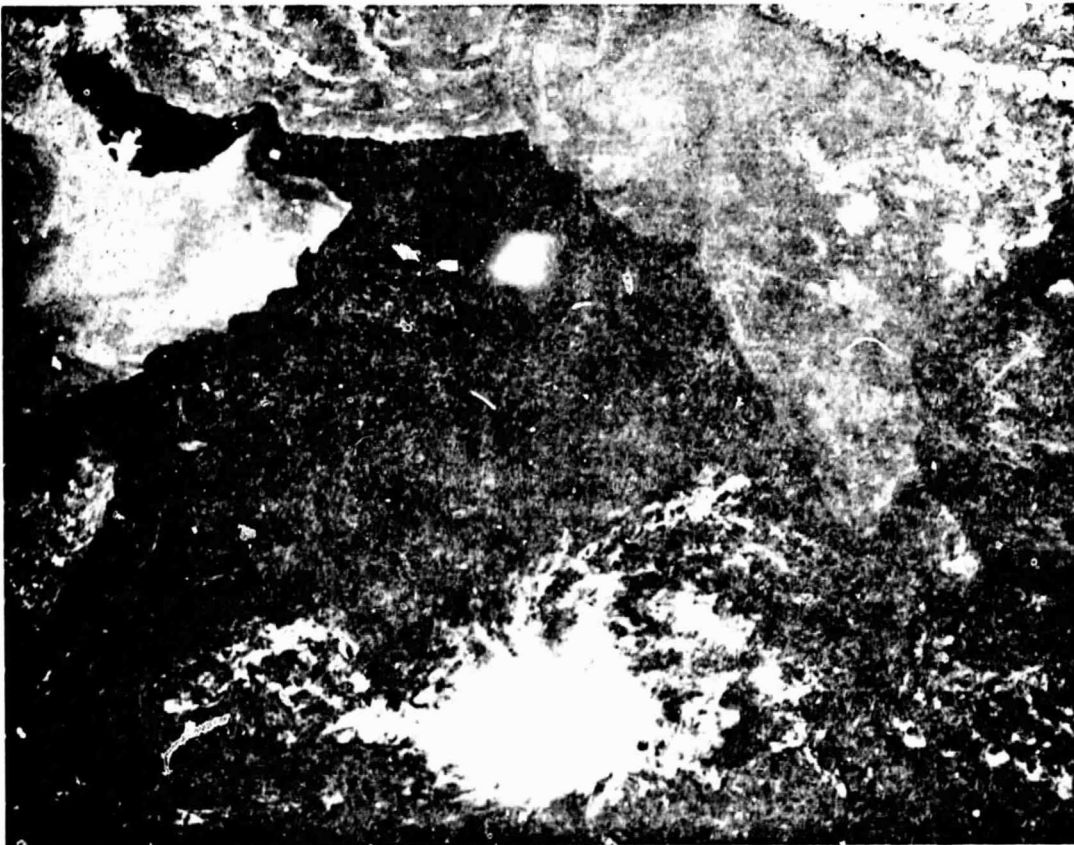


Figure 5: Satellite picture received on May 16, 1979

Recent satellite data reveal, for example, that the excess or deficiency of incoming solar radiation over the amount which the atmosphere loses to space is only of the order of 50 watts per square metre. Regions of excess in radiation show wide variations from year to year. It is possible that the performance of the monsoon is linked to this pattern of radiation balance over the MONEX region. The MONEX data could be utilised to study this linkage.

One way of investigating this aspect will depend on modelling experiments. Such experiments are designed to simulate the monsoon in all its facets by a mathematical model. If we begin with an initial state, albeit hypothetical, we could, with the help of an electronic computer, identify those features of the atmosphere which help to generate the monsoon. The model could help us to ascertain, in quantitative terms, what would be the response of the monsoon if some of these features, such as the input of solar radiation, was either increased or decreased.

It is a fairly well-known fact that the atmosphere is a highly turbulent medium in which a number of waves on different scales of motion are hurtling round the earth. How do these waves interact with each other to generate the weather producing systems, such as the monsoon depressions and the tropical cyclones? The accurate wind data, coupled with information on the thermal structure of the atmosphere, would help meteorologists in India to understand these physical processes. The data collected by the Indian research aircraft have shown that the monsoon depressions in the north Bay of Bengal are often generated in region of strong thermal contrast. Hitherto, it was widely believed that these depressions were merely cyclonic vortices emitted in regions of

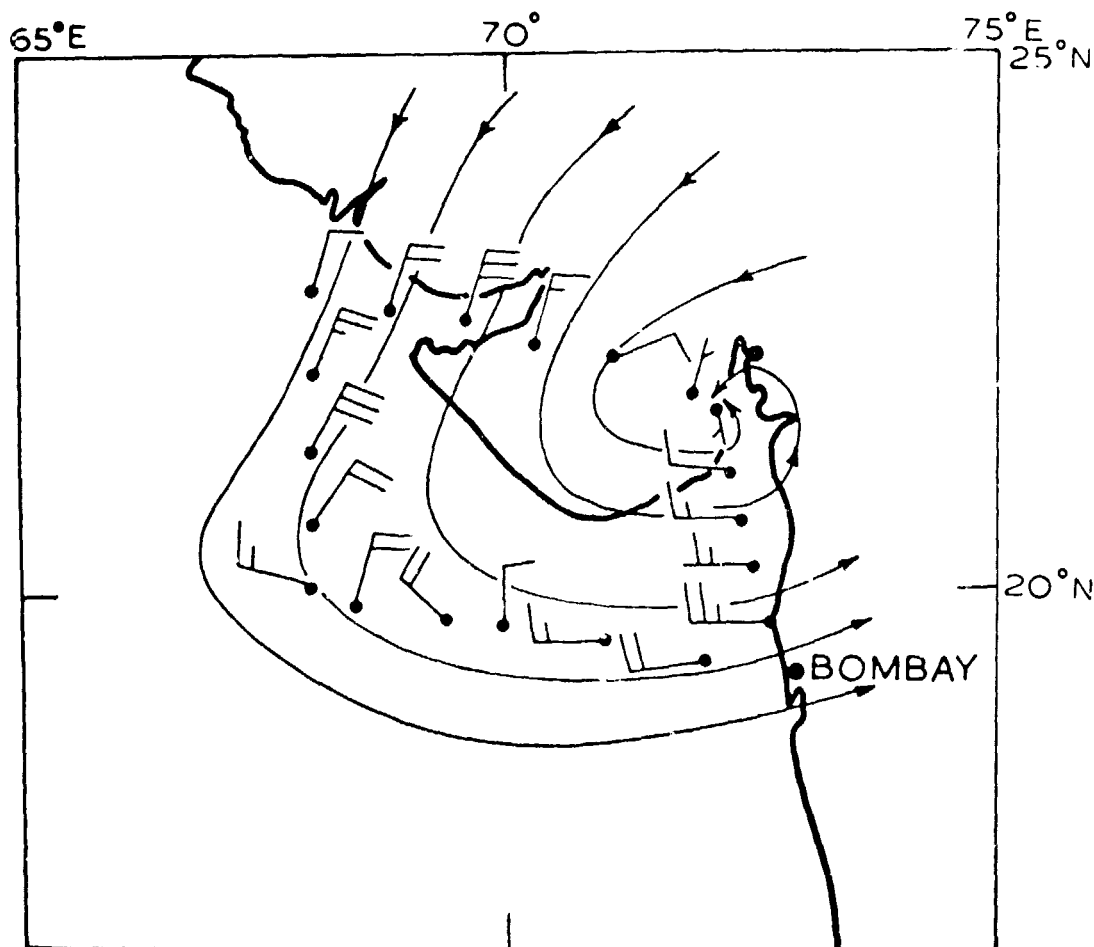


Figure 6 : Winds observed around a mid-tropospheric low by the Indian aircraft

weak or no thermal contrast, but recent aircraft data suggest a temperature gradient of 6-8° C over a distance of 500 km. The interaction between the thermal and wind fields raises several interesting possibilities, which have a bearing on the genesis of the monsoon depressions.

Short term changes in the monsoon rainfall are mainly the result of : (i) depressions in the Bay of Bengal, (ii) mid-tropospheric low pressure system over Gujarat, and (iii) the north-south movement of an elongated low pressure zone over the Gangetic zone, known as the monsoon trough. By way of an illustration, we indicate the winds that were observed around a mid-tropospheric low by the Indian aircraft during one of its flights (Figure 6). We could not have acquired such data over a small region by conventional means. The MONEX data will help us to identify these systems with much greater accuracy.

There is an increasing realisation that in addition to features of regional interest, such as the depressions and vortices of small dimensions, the monsoon is a much larger phenomenon which makes a big impact on the global circulation of the atmosphere. Observations are beginning to emerge which suggest that a lean monsoon over India is often balanced by abundant rainfall in some other parts of the world or vice-versa. Hitherto, we had envisaged the global circulation of the atmosphere in terms of Hadley or anti-Hadley cells. These cells were either driven by an excess of radiation near the equator, or at mid-latitudes by the rotation of the earth. It has been conjectured that there exist large-scale circulations of another type, oriented in an east-west direction which are perpendicular to the Hadley and anti-Hadley cells. The dynamics of these cells is still obscure because the data for this purpose were not available, but there is the interesting possibility that by monitoring the intensity of these atmospheric circulations (east-west cells) in other parts of the world we could anticipate the performance of the monsoon over India.

It is not too much to expect that, as a result of MONEX, our understanding of these aspects will improve in the near future. The MONEX data will, we hope, enable us to ultimately improve our capability to predict the behaviour of the monsoon. This experiment represents a significant step towards helping the rural sector of India through better information on the changes in weather.